



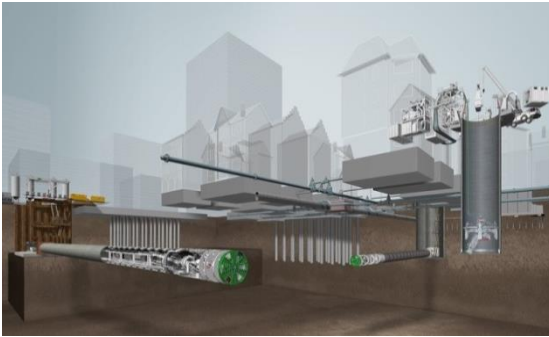
Trenchless technologies for small diameter tunnels.

Lutz zur Linde, Herrenknecht AG.

Bergen, June 07th, 2016

Herrenknecht Tunnelling, Machine range Ø < 4.2m

Utility Tunnelling – Business Segments.



► Utility Tunnels & Shafts

- Water & Sewage
- Casing tunnels for pipelines and cables
- Intake, outfall, landfall tunnels
- Shaft construction

► Pipeline

- Oil and Gas
- High pressure lines
- Fluid storage
- Extraction of natural resources
- Investigation and probe drilling

► Energy

- Offshore foundations
- Hydropower solutions
- Offshore – Onshore connections
- Onshore Network Expansion

Herrenknecht Group.

Small and large diameters.



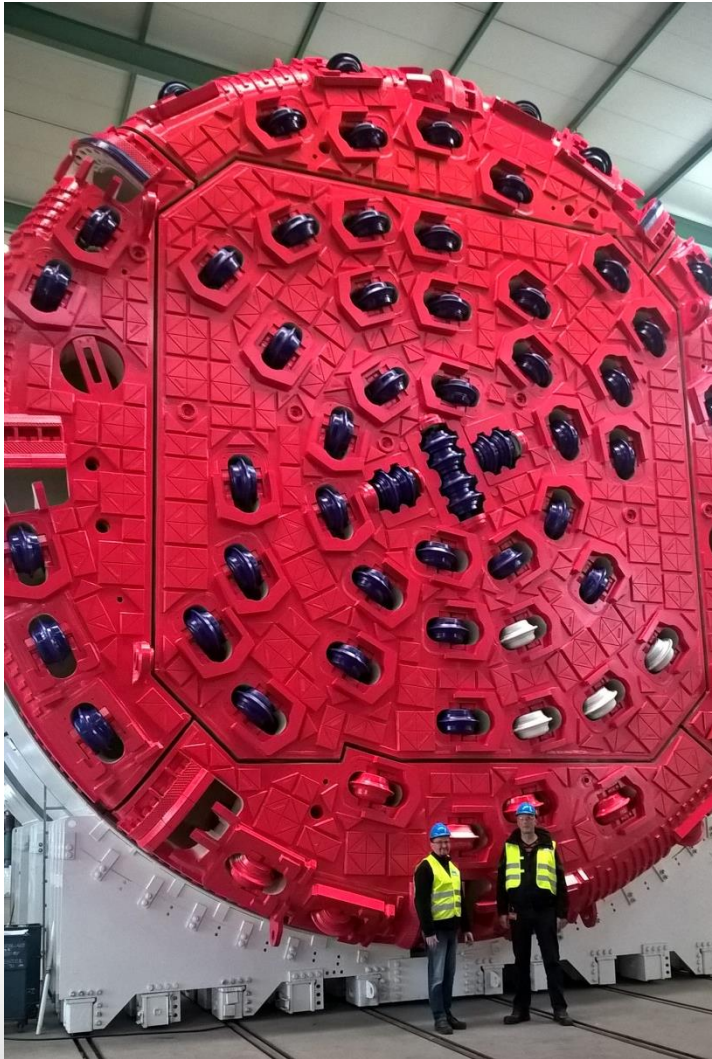
Microtunnelling Machine AVN400 Ø 0,56m



Hong Kong Mixshield Ø 17,60m

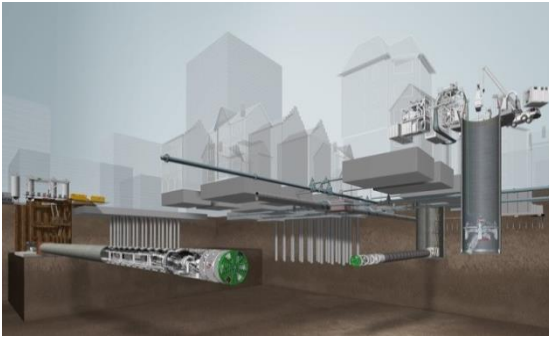
Herrenknecht. Pioneering Underground Technologies

Large Double Shield TBMs for Follo railway line Ø 9,96m



Herrenknecht Tunnelling.

Utility Tunnelling – Business Segments.



► Utility Tunnels & Shafts



► Pipeline



► Energy

► Machine range Ø < 4.2m.



AVN & AVND



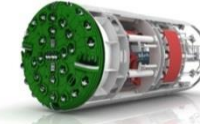
EPB Shield



Gripper TBM



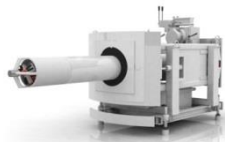
Single Shield



Double Shield



Partial-face
Excavation Machine



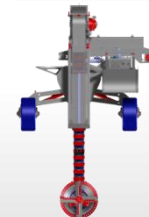
Auger Boring Machine



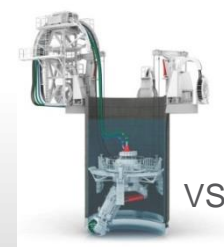
HDD Rig



Direct Pipe®



Pipe Express®



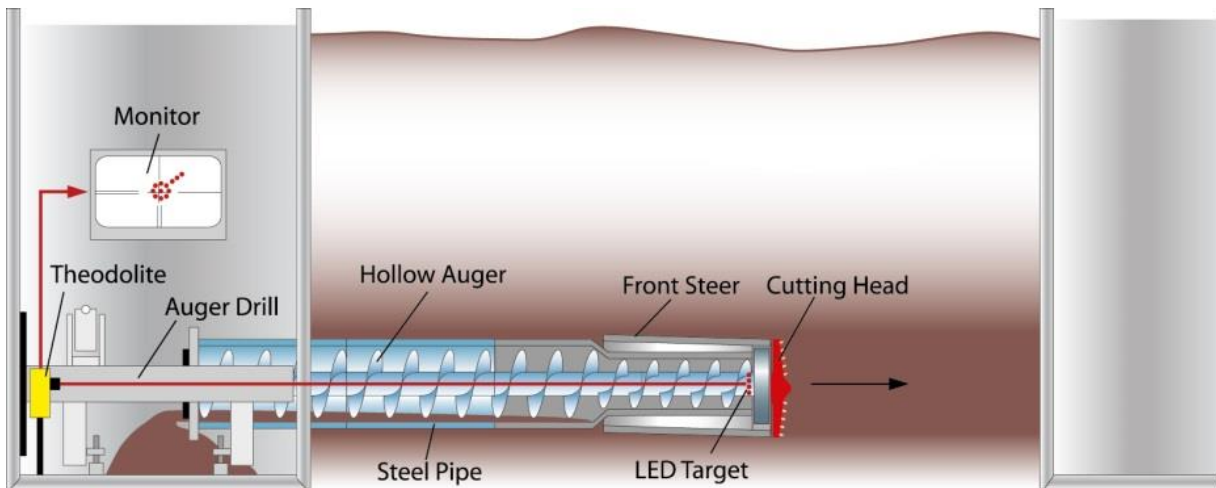
VSM

Herrenknecht. Pioneering Underground Technologies

Front Steer Auger Boring.

General functional principle.

- Guided by theodolite and monitor



- For compacted soil SPT > 35 and soft rock < 10MPa
- Different diameters
- Different cutterheads



Front Steer Auger Boring.

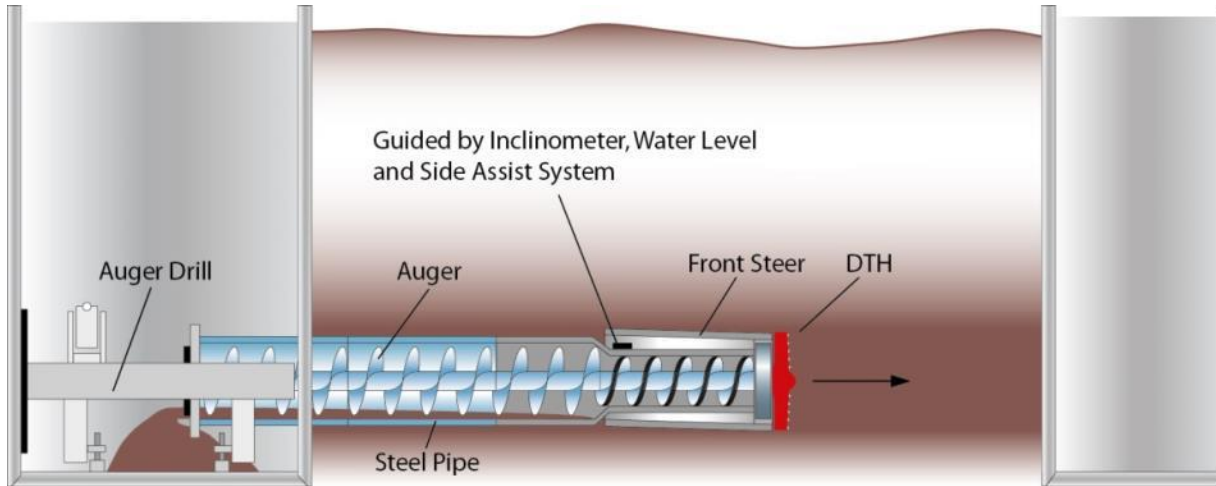
General functional principle.



Front Steer Auger Boring.

With Down-the-Hole Hammer (DTH) in rock.

- Guided by inclinometer, water level and side assist system



Front Steer Auger Boring.

With Down-the-Hole Hammer (DTH) in rock.

- Reference project, Switzerland



Front Steer Auger Boring.

Advantages.

- ▶ Low Capital Investment
- ▶ Short Setup Times
- ▶ Simple Operation
- ▶ Can be used in non-displaceable ground up to Rock
- ▶ Can be adapted to all Auger Boring Jacking Frames
- ▶ Can be equipped with a Down-the-Hole Hammer
- ▶ Control of Line and Grade with Inclinometer and Electronic Hydrostatic Water Level



Microtunnelling AVN 600 Citytunnelling.



Västra Länna Sewage Line, Stockholm, Sweden.

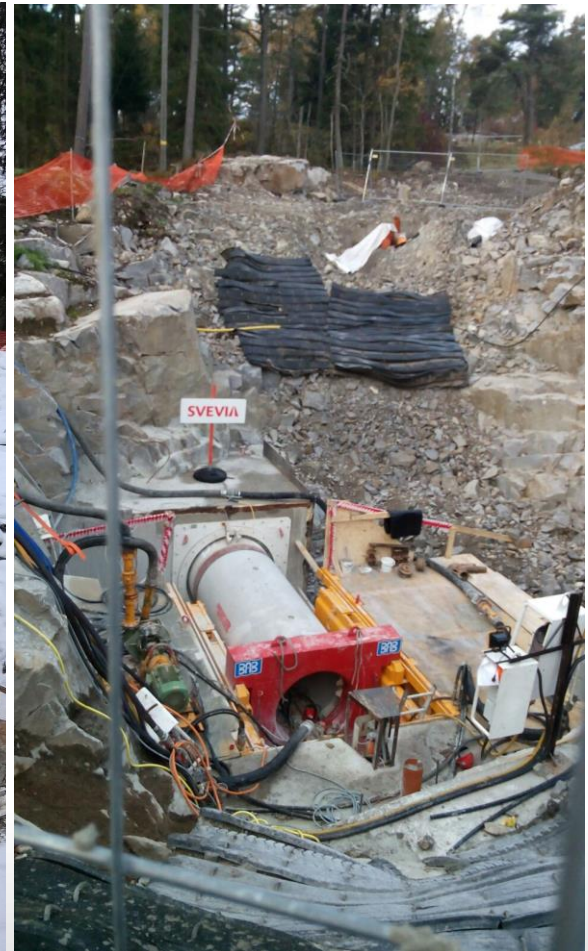
AVN1200TB for hard rock tunnelling; L=165m

- ▶ M-1948M, AVN1200TB, OD1490mm
- ▶ Location: Huddinge, Stockholm, Sweden
- ▶ Geology: Swedish hard rock, granite
 - ▶ UCS: 150-223MPa / CAI 5,2
- ▶ Contractor: BAB Rörtryckning AB
- ▶ Client: Stockholm Vatten



Västra Länna Sewage Line, Stockholm, Sweden.

AVN1200TB for hard rock tunnelling.



Västra Länna Sewage Line, Stockholm, Sweden.

AVN1200TB for hard rock tunnelling.



Nissan River Crossing in Halmstad, South of Sweden.

AVN1200TB used.

- ▶ M-1948M, AVN1200TB, extended to ID1400, OD1720mm
- ▶ 93m sewage tunnel built in only 10 days!



Reference Project: Budapest, Hungary.

Danube River Crossing in mixed geology.

- ▶ M-732M, reinforced concrete pipe ID1400/OD1720mm
- ▶ 1 x sewage tunnel installed under Danube river
- ▶ Deep Shafts: 23m
- ▶ Curved drive: long drive of 635m with horizontal curve



Reference Project: Budapest, Hungary.

Danube River Crossing in mixed geology.

- Mixed Geology: Limestone, Marl, Clay, Silt and Sand



Herrenknecht Premiere for AVN 1600TB.

First Microtunnelling Jobsite in Czech Republic: Sewer under the Royal Garden of the Prague Castle

- ▶ M-595M, AVN1600TB, OD1960mm
- ▶ Location: Prague, Czech Republic
- ▶ Tunnel length: 200m
- ▶ Contractor: Energie - stavební a bánská a.s.
- ▶ Tunnelling Duration: Nov 22nd – Dec 30th, 2013



AVN 1600 in 40m deep launch shaft in Prague.

Herrenknecht Premiere for AVN 1600.

First Pipe Jacking Jobsite In Czech Republic.

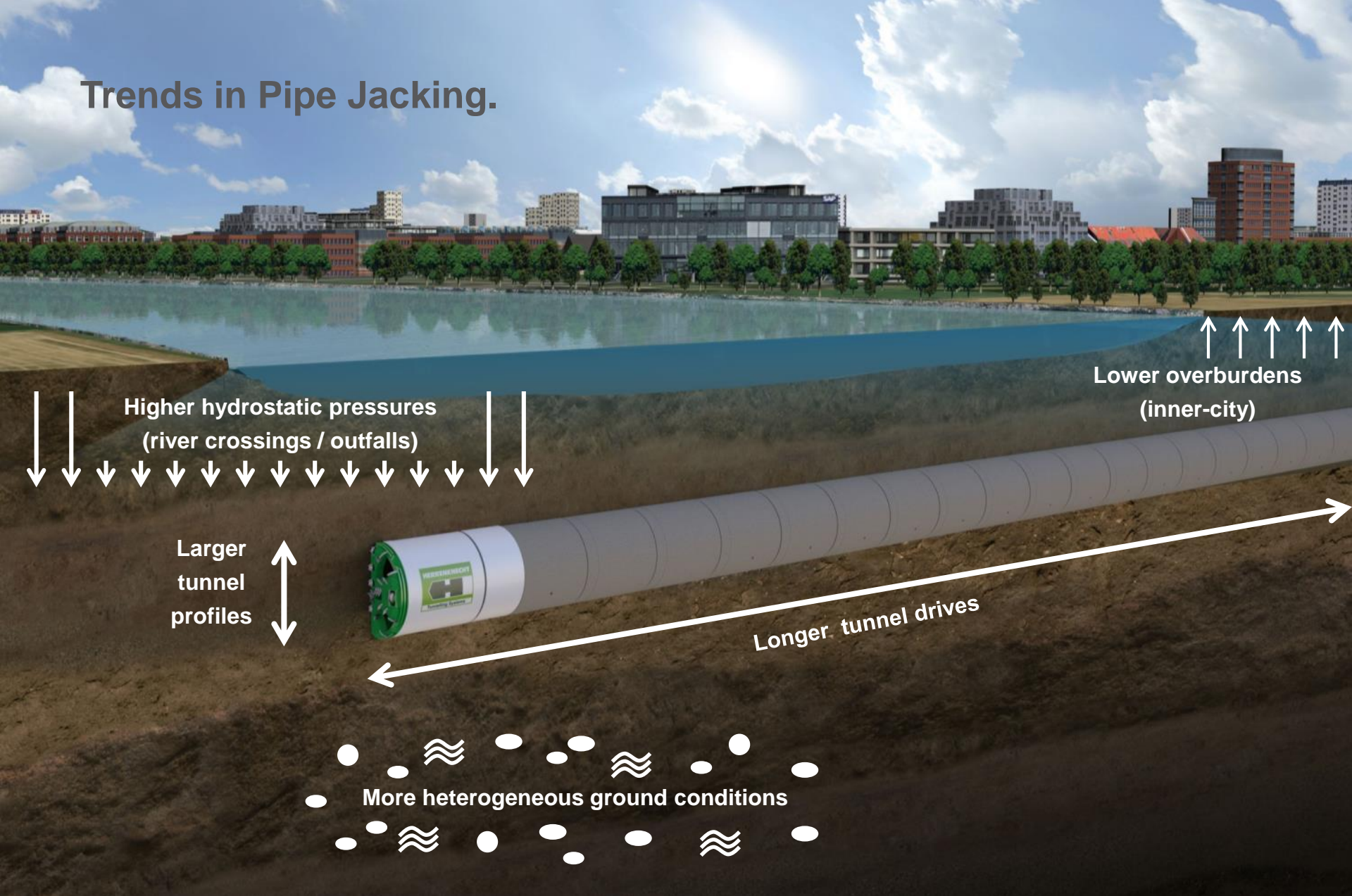


Hobas Jacking Pipes, ID 1800



Pipe Jacking equipment installed on jobsite under restricted surface conditions.

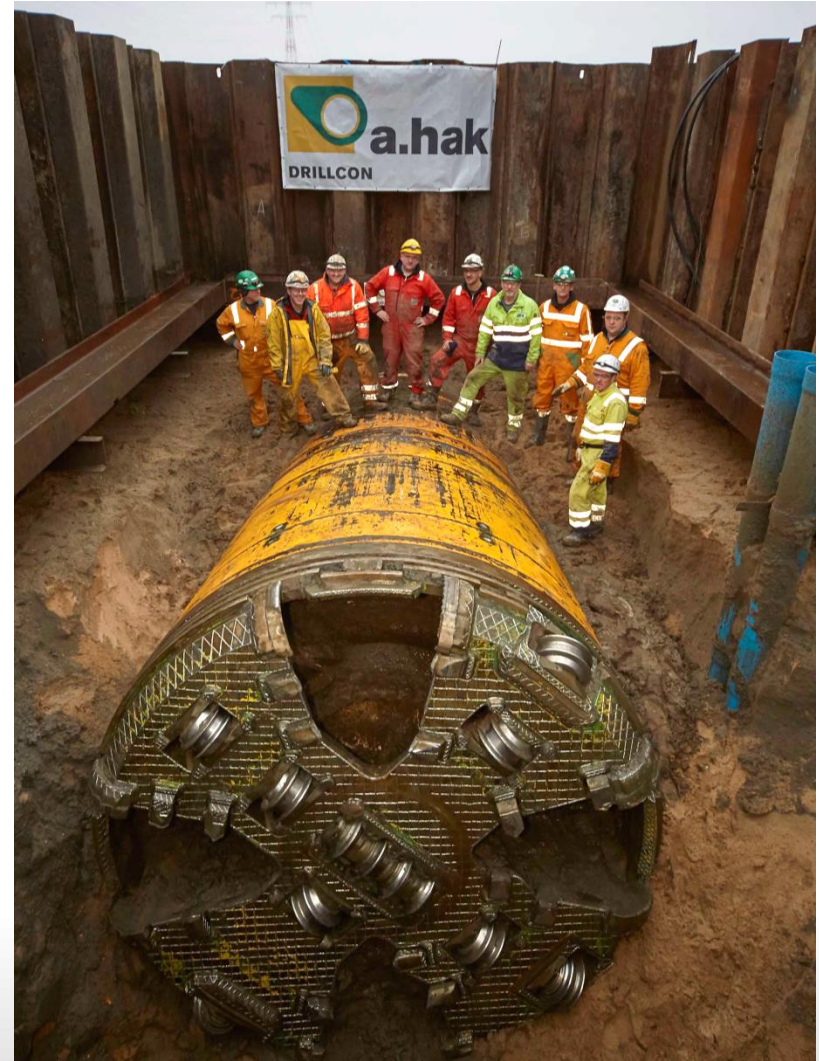
Trends in Pipe Jacking.



Elbe Crossing in Hamburg, Germany.

Pipe Jacking for gas pipeline.

- ▶ M-1439M, AVN2500, OD3000
- ▶ Casing for 2 gas pipelines for Gasunie
- ▶ 1,580m advance in 112 days
- ▶ Up to 4 bar groundwater pressure
- ▶ Breakthrough: December 4, 2014



Sea Outfall Project Sochi, Russia.

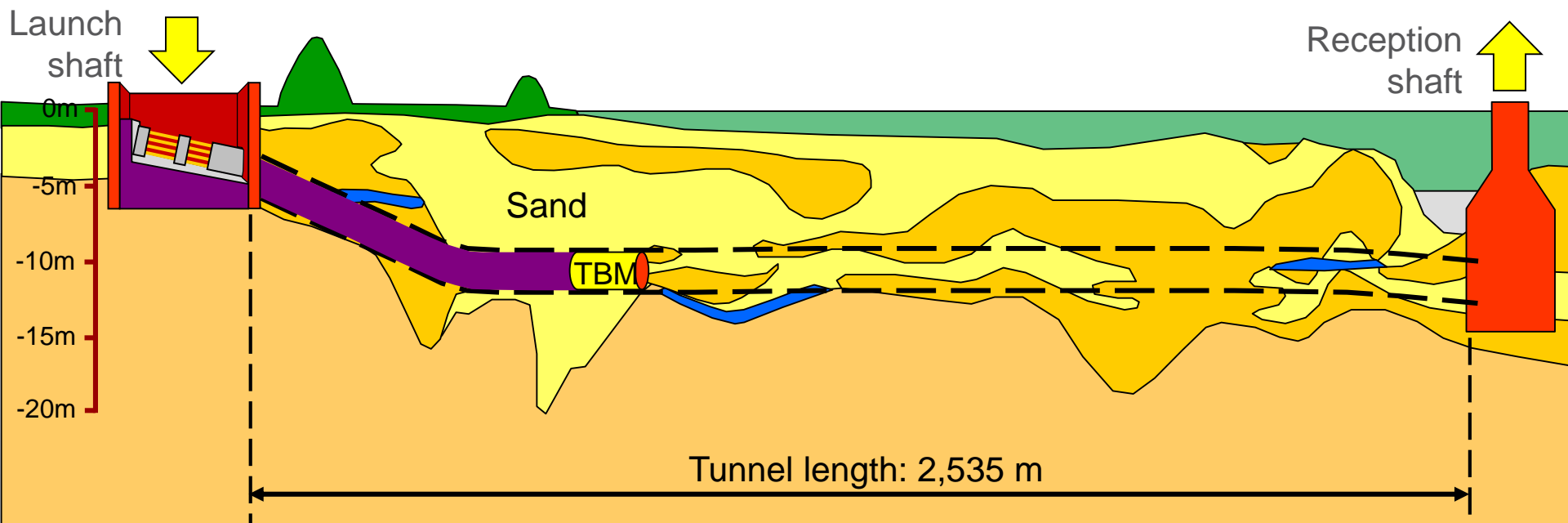
Two pipe jacked outfalls in the Black Sea.

- ▶ M-1103M, AVND 2000, OD 2525.
- ▶ 2 Sewage tunnels installed under the Black Sea, 1,411m + 2,014m.
- ▶ 2,014m = Long distance record in ID 2000 | First Sea Outfall in Russia.
- ▶ Geology: clay, limestone, argillite
- ▶ Performance: 2,014m tunnel installed in 100 days.

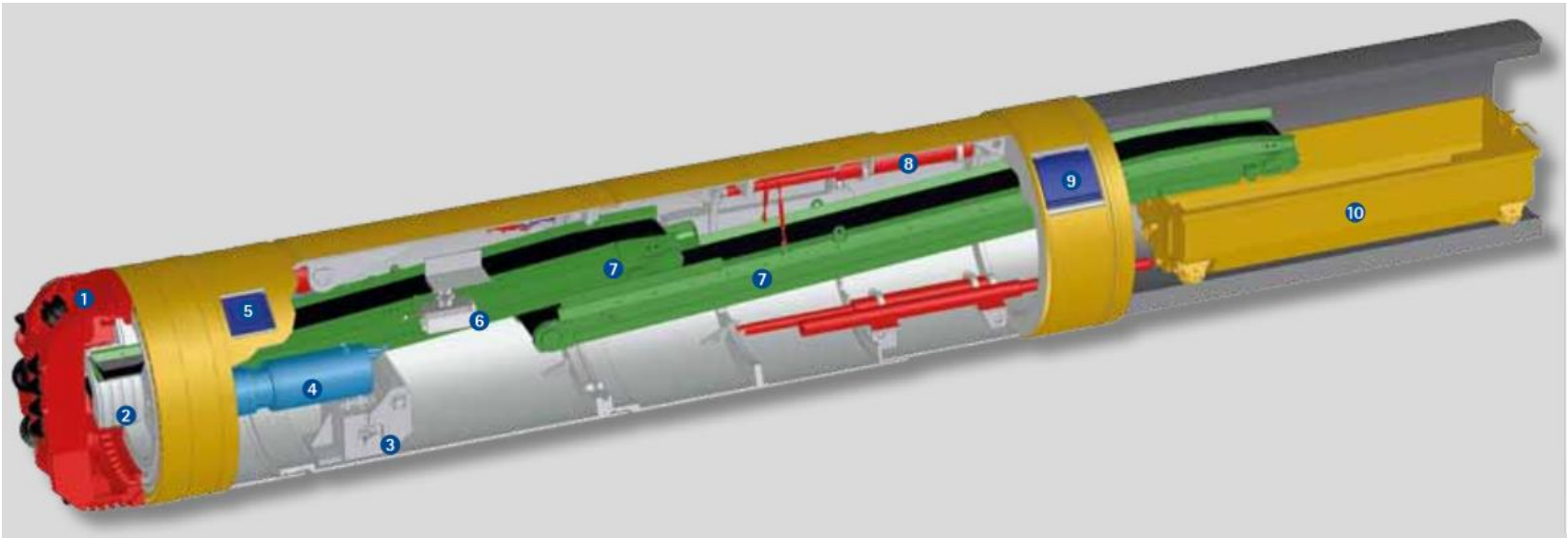


Reference Project: Europipe, Germany.

2,535m Pipe Jacking in the North Sea in 1994.



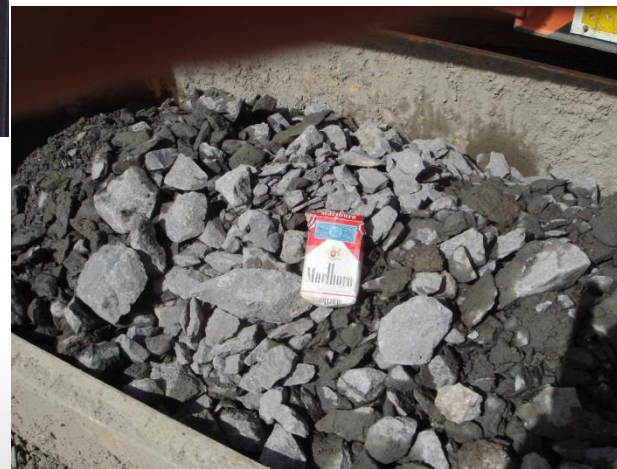
Hard Rock Pipe Jacking TBM.



- | | |
|------------------|----------------------|
| 1 Cutting wheel | 6 Target/Gyro |
| 2 Muck ring | 7 Belt conveyor |
| 3 Winch | 8 Telescopic Station |
| 4 Electric motor | 9 Gripper |
| 5 Stabilizer | 10 Muck Skip |

Hard rock TBMs for Pipe Jacking.

TBM 1200.



Advantages of TBM Technology

- ▶ Lower investment compared to Slurry Equipment
- ▶ Lower operational costs / no separation plant
 - No water, no disposal cost, no wear in slurry equipment)
- ▶ Designed to cut the hardest rock (11" discs – max. 250 MPa)
 - high thrust capacity
- ▶ Easy and fast maintenance of cutting wheel (change of cutters)
- ▶ Simplified equipment → lower maintenance and repair cost
- ▶ High penetration rates
- ▶ Fast set-up and Launching times

TBM1600 for Hard Rock Tunnelling in Madinah / KSA. Jobsite Setup.



TBM1600 for Hard Rock Tunnelling in Madinah / KSA.

Launch shaft with Muck Skip for Soil removal.



TBM1200 for Hard Rock Tunnelling in Madinah / KSA. Launch Shaft.



TBM1200 for Hard Rock Tunnelling in Madinah / KSA.

Excavated Soil.



Tunnel Lining in rock conditions.

Depending on Rock Classification we use different different TBM types.



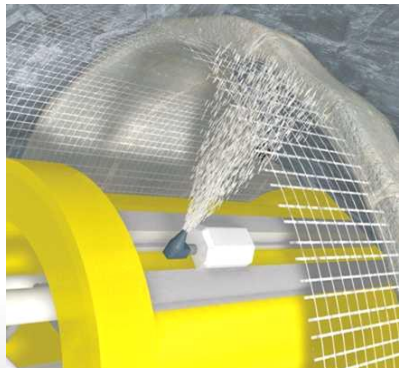
▶ without Lining



▶ Rock Bolting



▶ Mesh & Beam



▶ Shotcrete



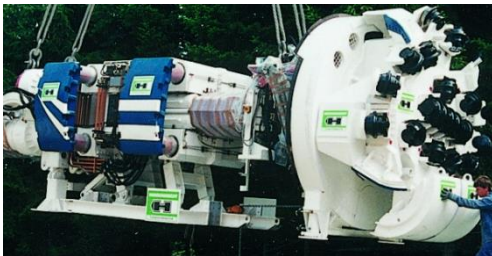
▶ Rib & Lagging



▶ Segment Lining

Machine types for rock conditions.

Non-Shielded TBMs



- ▶ Mainbeam Gripper TBM
- ▶ Cutting $\varnothing > 3600\text{mm}$

Partly-Shielded TBMs



- ▶ Micro Gripper TBM
- ▶ Cutting $\varnothing > 2580\text{mm}$

Shielded TBMs



- ▶ Single Shield TBM
- ▶ Cutting $\varnothing > 2800\text{mm}$

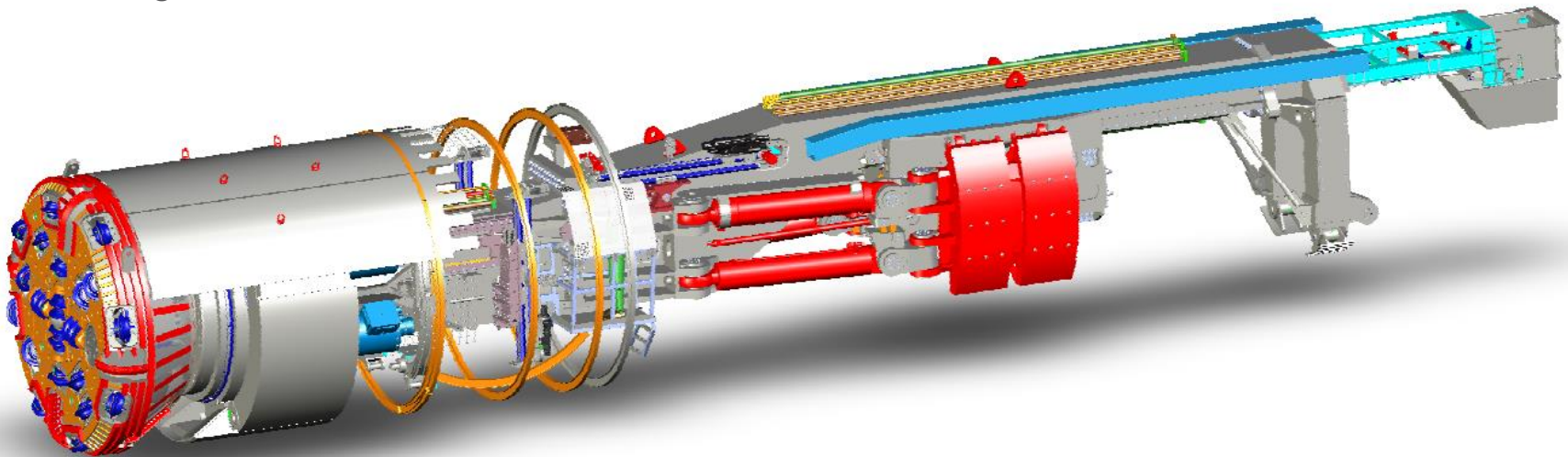


- ▶ Double Shield TBM
- ▶ Cutting $\varnothing > 2800\text{mm}$

Mainbeam Gripper TBM.

Main characteristics.

- ▶ Suitable for stable rock
- ▶ Temporary lining: roof bolting, mesh & beam, shotcrete
- ▶ Min. cutting diameter: 3600mm
- ▶ Production : 300-600m/month
- ▶ Lining close behind the Cutterhead



Bärenwerk Hydropower Plant.

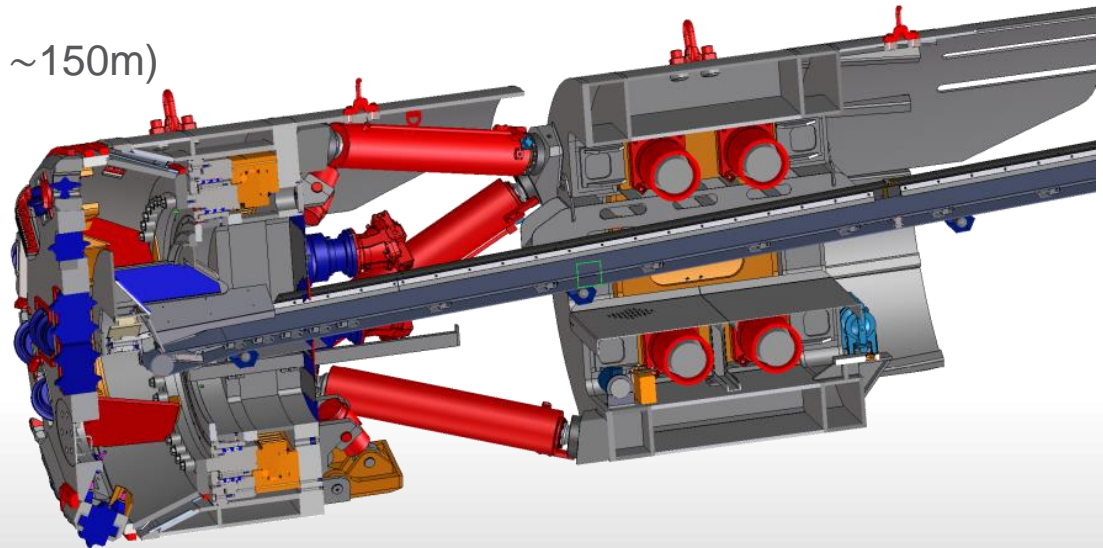
- ▶ S-800, Gripper TBM
- ▶ Diameter: 3,830mm
- ▶ Location: Fusch, Austria
- ▶ Application: Headrace tunnel
- ▶ Tunnel length: 2,818m
- ▶ Geology: Alpine rock
- ▶ Contractor: Marti Tunnelbau
- ▶ 5.5 months from kick-off meeting until factory acceptance test on February 15, 2013
- ▶ Start of tunnelling: April 2013
- ▶ Breakthrough: September 10, 2013



Micro Gripper TBM.

Main characteristics.

- ▶ Suitable for stable rock
- ▶ Temporary lining: roof bolting, mesh & beam
- ▶ Min. cutting diameter: 2580mm
- ▶ Production : 250-500m/month
- ▶ Compact design
- ▶ Suitable for tight curves ($r = \sim 150\text{m}$)



Micro Gripper TBM.

Reference Project: Rio Vermelho HEPP.

- ▶ M-1848M, Gripper TBM 2850 retractable
- ▶ Location: Sao Bento do Sur, Brazil
- ▶ Use of tunnel: Water tunnel for Mini-HEPP Project
- ▶ Tunnel length: 7.7km in 6 drives
- ▶ First 800m drive: completed in 2015
- ▶ Geology: rock
- ▶ Contractor: KM26 - Caldeiraria e Madeireira LTD
- ▶ First 2 Multi-Service-Vehicles in use for Utility Tunnelling machine
 - ▶ Most “slim” version of MSV ever built



Rio Vermelho Hydropower Project.

Retractable Gripper machine.

► Drives overview:

- 1. drive 800m straight, 0,4% uphill
- 2. Tunnel: 550m, straight, 5% uphill
- 3. Tunnel: 3000m, 300m curve radius, 0.4% uphill
- 4. Tunnel: 750m, 5% uphill
- 5. Tunnel: 280m, straight
- 6. Tunnel: 2350m, >300m radius, 4,3% downhill, TBM retraction through tunnel



- Well suitable for stable hard rock
- Compact machines for small HEPP
- Small curves Min. R = 150m
- 14" discs – max. UCS ~ 350 MPa

Rio Vermelho Hydropower Project.

First 2 Multi-Service-Vehicles in use for Utility Tunnelling machine

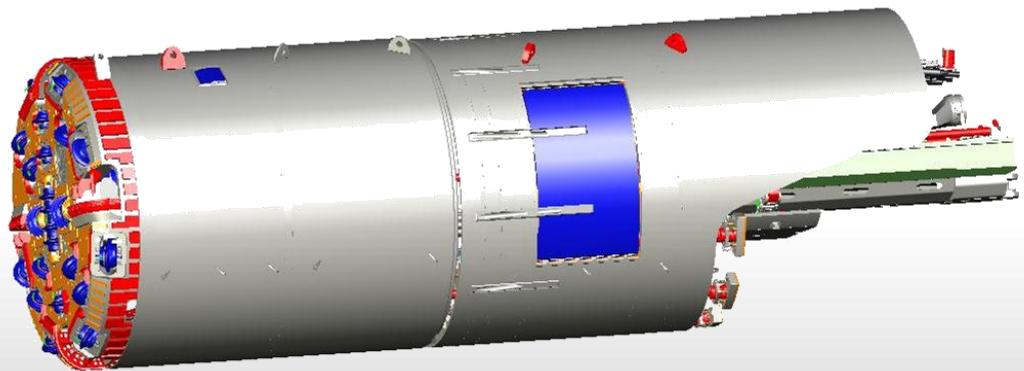
- Most “slim” version of MSV ever built



Double Shield TBM.

Main characteristics.

- ▶ Suitable for instable rock
- ▶ Permanent lining: Concrete segments
- ▶ Min. cutting diameter: 2800mm
- ▶ Production : 400-600m/month
- ▶ Excavation+lining can be done simultaneously
- ▶ Multifunctional use as Gripper, Single Shield and Double Shield possible
- ▶ High advance rates in gripper and double shield mode



Double Shield TBM.

Reference Project: Inelfe HDVC Link France - Spain

- ▶ M-1619M+M-1620M, 2 x TBM 3500 , OD 4265mm, „Alberas & Canigou“
- ▶ High-voltage cable tunnel
- ▶ Tunnel length: 8,261m (from South: 7,026m, from North: 1,235m)
- ▶ Geology: abrasive rock, schist, Gneiss, Diorit, Granite, 150 MPa
- ▶ Contractor: JV Eiffage-Dragados



Double Shield TBM.

Reference Project: Inelfe HDVC Link France - Spain

- ▶ Best daily performance: 53.5m (M-1620M, 24.06.2012)
- ▶ Best monthly performance: 1.040m (M-1620M, September 2012)
- ▶ Special machine design for disassembly of both machines in the tunnel, without cavern. machines reusable

- ▶ Breakthrough of M-1620M in finished tunnel of M-1619M on April 17th, 2013.



Double Shield TBM.

Reference Project: Uma Oya Multipurpose Project in Sri Lanka.

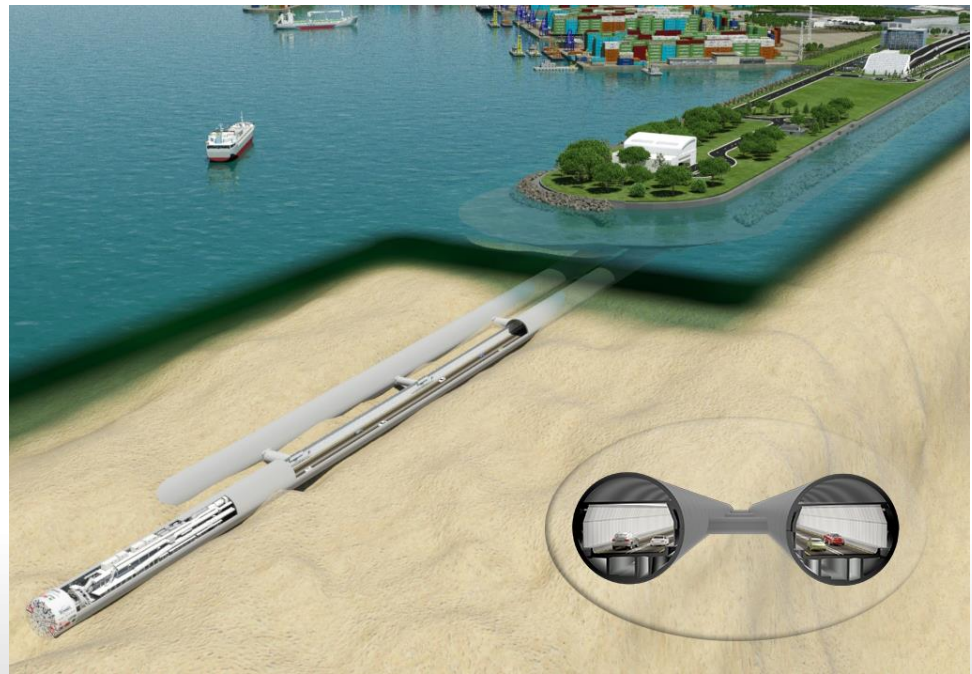
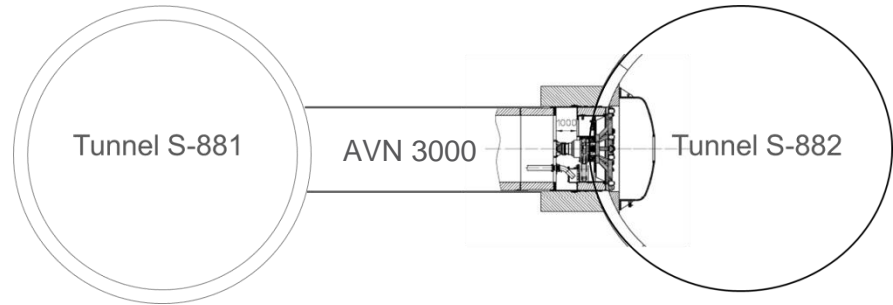
- ▶ M-1684M, M-1685M, 2x TBM3600XH, OD 4240 mm
- ▶ Location: Uva Province, Sri Lanka
- ▶ Tunnel length: 3.3 km Trailrace + 15.6 km Headrace
- ▶ Geology: hard rock with max. 250 MPa compr. strength
- ▶ Contractor: Farab



Tuen Mun-Chek Lap Kok Link.

Hong Kong. Cross Passages with AVN 3000.

- ▶ M-2001M + M-2003M
- ▶ 2 x AVN 3000, OD 3605
- ▶ 44 Cross passages will connect the two road tunnels
- ▶ Length: 14m each



Tuen Mun-Chek Lap Kok Link.

Hong Kong. Cross Passages with AVN 3000.

- ▶ First breakthrough: March 31st, 2016
- ▶ Tunnel length: 10.82m
- ▶ Max. confinement pressure: 5,5 bar



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A member of the Bouygues Construction group

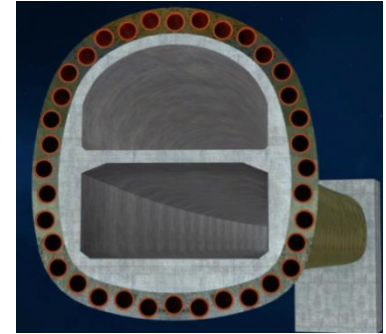


Dragages - Bouygues Joint Venture 寶嘉 - 布依格聯營

GongBei Pipe Arch. Hong Kong - Zhuhai - Macao Bridge.

Road tunnel along the border Macao - Zhuhai.

- ▶ Connection of the 30km long bridge to the mainland
- ▶ 4 x AVN1200TC | OD 1640 + 2 x HKS 300 Separation plants
- ▶ Geology: sand, fine sand, clay
- ▶ 36 drives of 255m length each
- ▶ Curve radius = 250m



GongBei Pipe Arch. Hong Kong - Zhuhai - Macao Bridge.

Road tunnel along the border Macao - Zhuhai.

- All 36 drives finished in May 2015



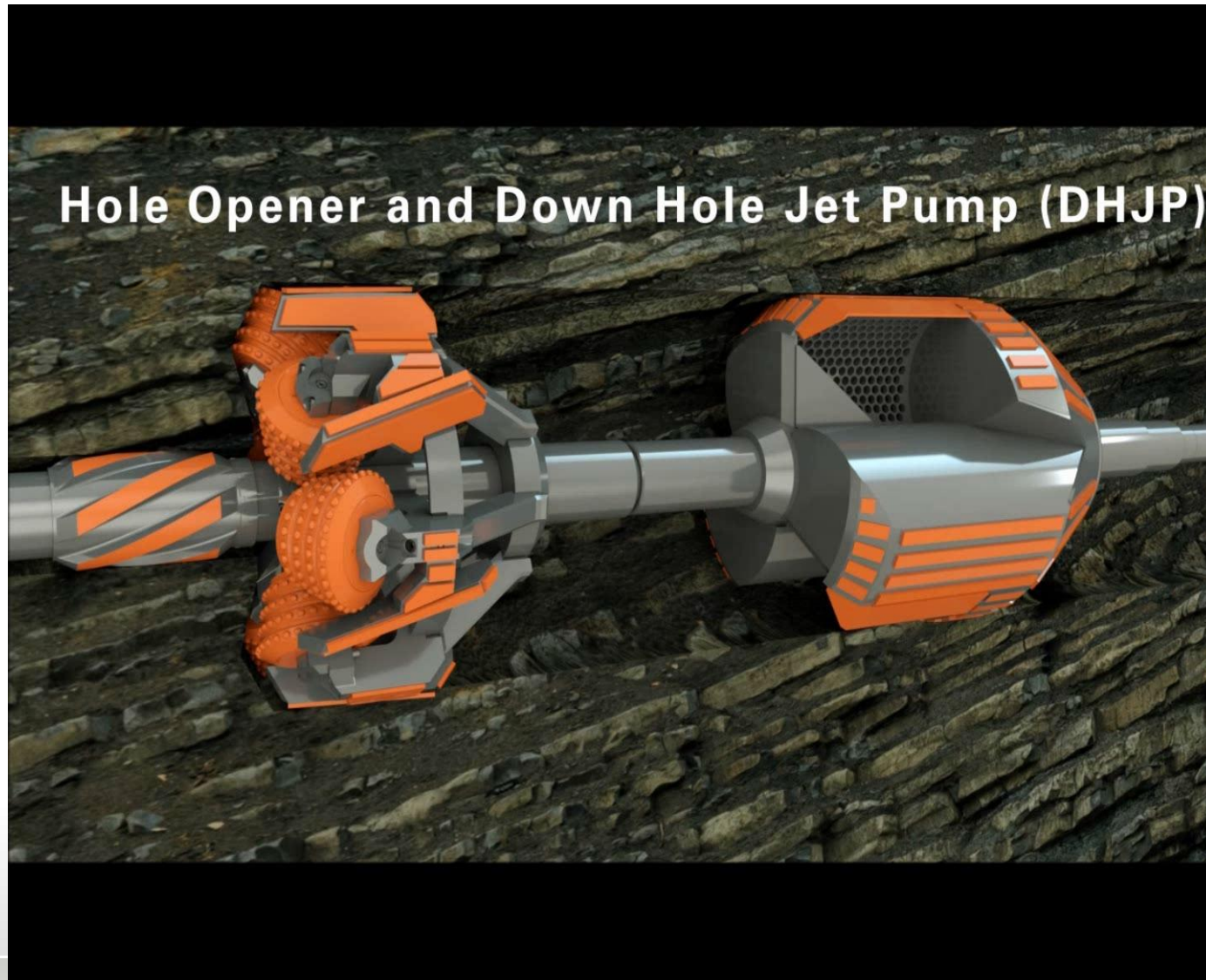
Slant Directional Drilling Rig.

Reference project Mongstad, Norway.

- ▶ H-026, HK250T
- ▶ Entry angle: 45°
- ▶ Landfall of a gas pipeline
- ▶ Borehole diameter: 14"
- ▶ Final depth: 234m (below sea level)
- ▶ Drilling length: 416m
- ▶ Geology: Basalt, 276MPa
- ▶ Contractor: Visser & Smit Hanab



Full Face Hole Opener & DHJP







Thank you !

Contact @ Herrenknecht

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- ▶ [mailto: zurlinde.lutz@herrenknecht.de](mailto:zurlinde.lutz@herrenknecht.de)

